LESSON 25 – RANGING AND RESOLUTION
(Problem Set 3 due; Pick up Problem Set 4)
Last lesson we saw that pulse width was ultimately the limiting factor in target range resolution. We now investigate several techniques for overcoming that limitation.

Reading:
Stimson **Ch. 13 (pp. 163-169), Ch. 14 (exclude sections on ghosting)**
Problems/Questions:
Finish Problem Set 3
Objectives:
25-1 Understand the concept of "chirp".
25-2 Be able to calculate the range resolution of a chirped pulse.
25-3 Understand how range can be indirectly measured through linear FM modulation of the radar signal.
25-4 Be able to calculate target range using FM ranging techniques.

Last Time: Ranging Schemes
Resolution
Signal Strength/Noise
Ambiguities (PRF Jittering/PRF Switching)

Today: Ranging Schemes
Chirp/Pulse compression
FM Ranging

Equations: $R = c(\Delta F_1 + \Delta F_2)/(4*\text{slope})$ for FM Ranging

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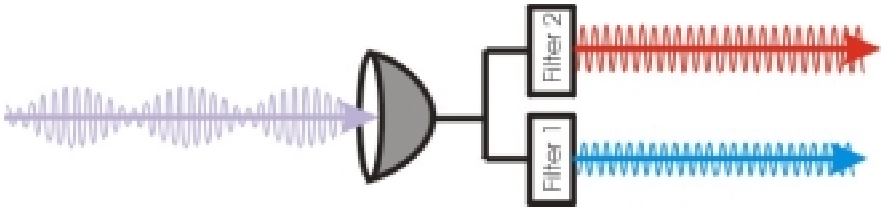
What was better, short or long pulses? Why?

Why don't we make our pulses EXTREMELY short?
Not enough energy in the return to be discernible above the noise.

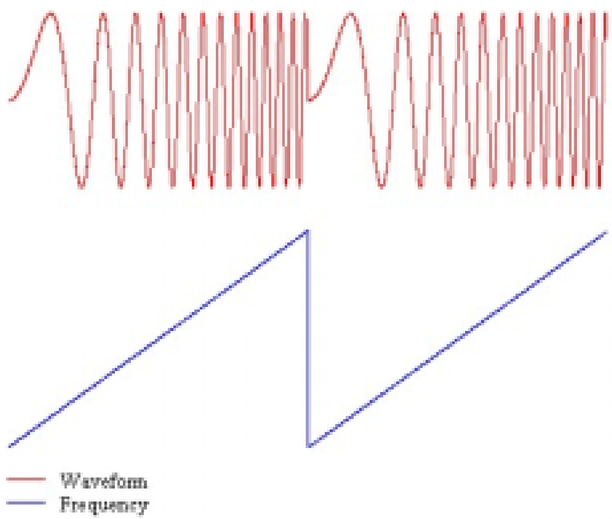
Our problem: we need short pulse widths for range resolution but are limited by our equipment to longer pulse widths to get enough energy in the signal to be detectable.

Explain filters (show a colored filter set as an example).

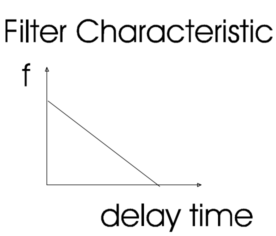
Filters take information containing a huge number of frequencies and only allow specific frequencies to pass. Perfect filters only allow 1 frequency out (but the power out of such a filter would be infinitesimally low).

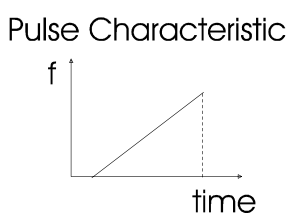


Imagine a pulse that continuously increases the frequency of its carrier throughout its width. This is called a CHIRPED signal, since it sounds like a bird chirping.



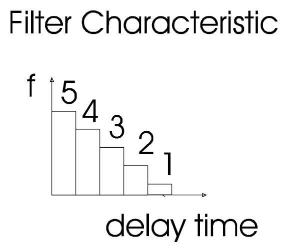
If the return in passed through a set of filters that have different delay times, we can rearrange this pulse. Let's look at a filter with a delay response like the following figure:

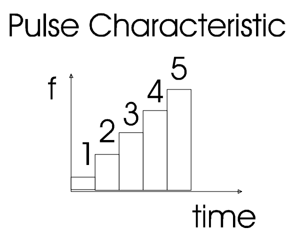




Low frequency = long delay, high frequency = no delay.

Instead of looking at a single pulse, it's easier to visualize a "step-pulse" and a "step-filter" like the following figures:





As this pulse passes through this filter, f_6 shows up first and is delayed longest, followed by f_5 which is delayed a little less, and so on until f_1 shows up and is not delayed at all.

What is the output of this filter? We now have a high amplitude, short width pulse. What is this pulse's resolution? ½ the pulse width, right? So our six unit width pulse has a resolution of 3 units? Not quite. Look at the following figure and you'll see that the resolution is really half of the compressed pulse width. (this figure only show the return after it has reflected off of the target. That's why it looks like resolution is the whole compressed pulse width)

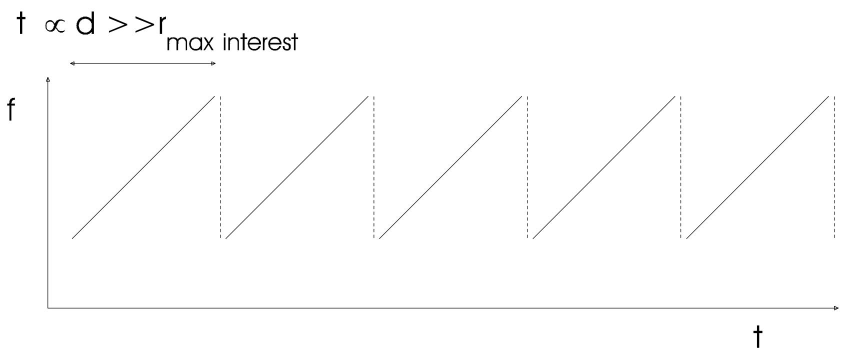
Show Chirp.avi

Now what is our limit on resolution? Our ability to make good, narrow band filters and the number of filters you are able to cram into the hardware, and also the resolution inherent in the wavelength of the radar.

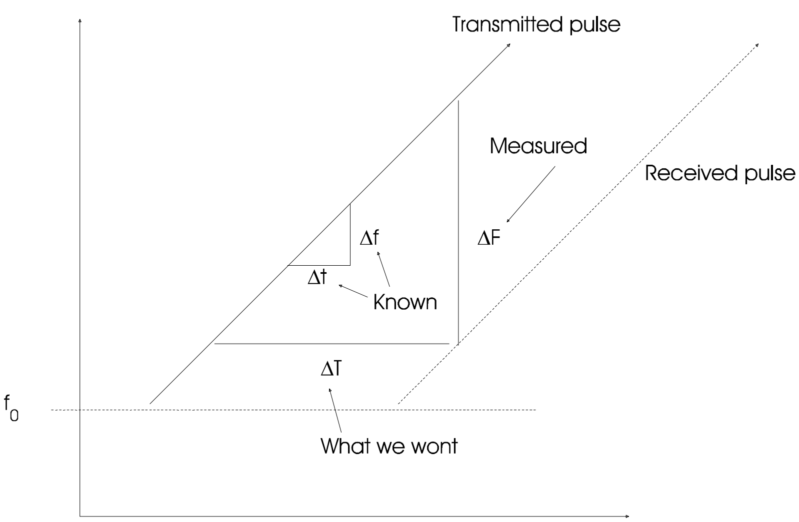
Let's move on to FM Ranging.

What happens to the unambiguous range as the PRF goes up? It goes down ($R_u = cT/2 = c/2prf$)

In order to resolve ambiguities, you need to start adding different PRFs, which makes the radar system more and more complex. If the PRF is high enough, it becomes too complicated to resolve at all. Why do we need to do this high PRF stuff? As we'll see later, high PRF => lots-o-range ambiguities, but it also minimizes Doppler ambiguities. The bottom line, if you really want to know how fast something's going, you need a really high PRF.



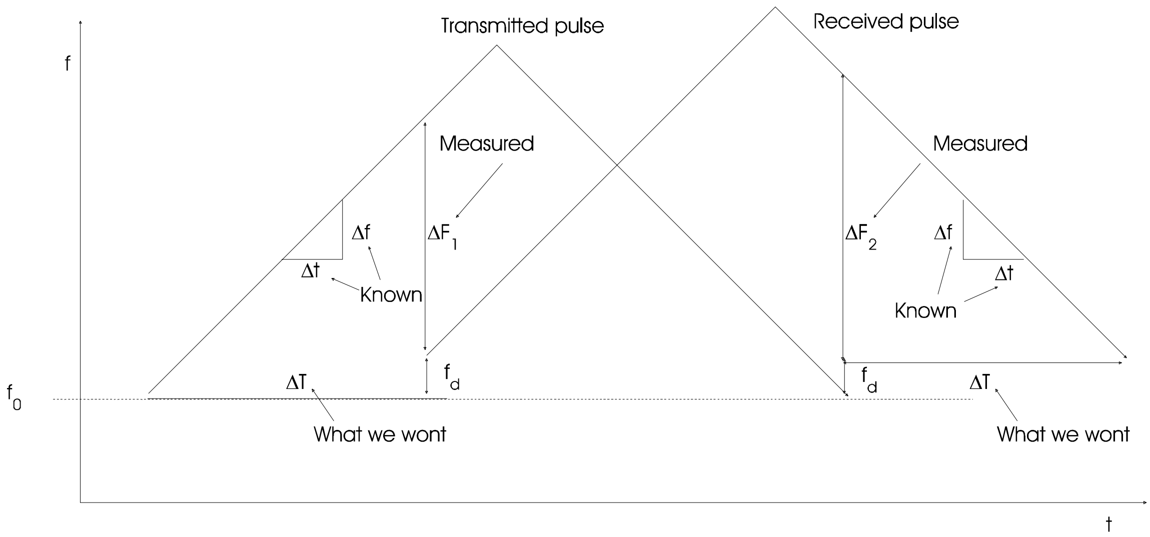
What's the limit of high prf? Continuous waves. But earlier we said that we needed to pulse the radar to get range information. That's not exactly true. It's just the simplest way to do it, especially when we already need to share the antenna. Another way to get range information exists that uses a quasi-CW signal and sweeps the frequency, similar to the chirped signal we looked at earlier.



If we look in detail at one pulse and its return, we can see from geometry that $\Delta f/\Delta t = \Delta F/\Delta T$, so $\Delta T = \Delta F(\Delta t/\Delta f)$.

But from our range equation, $R = c\Delta T/2 = c[\Delta F(\Delta t/\Delta f)]/2$, but $\Delta f/\Delta t$ is just the slope, so the final equation becomes
$R = c\Delta F/(2*\text{slope})$.

But what if the target is moving? Then we'll have to do a double sweep of the frequency. From the following diagram, we see that $\Delta t/\Delta f$ = slope = $(\Delta F1+f_d)/tr = (\Delta F_2 - fd)/tr$



So

tr(slope) = DF1 + fd
tr(slope) = DF2 - fd

2tr(slope) = DF1 +DF2

tr = (DF1 +DF2)/2slope

R = ctr/2

R = c(DF1 +DF2)/4slope

Does this work for a non-moving target? Sure.